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NAVORD REPORT 1876

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EVALUATION OF THE FUZING SYSTEM FOR THE MISSILE "LOON" (JB-2)

12 August 1952

U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

SECURITY INFORMATION

54AA-57898

EVALUATION OF THE FUZING SYSTEM FOR THE MISSILE "LOON" (JB-2)

Prepared by:

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ABSTRACT: (a) The electric fuze T74E3 and the mechanical fuze T84E3 for the missile "LOON" (JB-2) have been evaluated for safety and operability as an item of shipboard ordnance. The mechanical fuze T84E3 was declared unsafe because it did not incorporate out-of-line detonator features, and was eliminated from the evaluation program. The electric fuze has been submitted to the Military Standard Transportation and Safety Handling Tests, the Standard Salt Spray Fuze Test and the Military Standard Temperature and Humidity Test. The fuze has also been armed and fired at -65°F and 160°F. A statistical analysis has been made to determine a measure of the arming-train safety and reliability of the fuze. Although lack of ruggedness in design of the electrical fuze T74E3 is greatly emphasized by the Transportation and Safety Handling Tests, the fuze appears to be reasonably safe and reliable.

(b) Full scale field tests of the modified fuzing system for the missile "LOON" were conducted at the U. S. Naval Air Missile Test Center, Point Mugu, California. Three flights were made. The first was only partially successful because of short missile flight. The second and third flights were successful. The second flight was a telemetered flight launched from the shore. The third was a service condition flight launched from a surfaced submarine. The results of these tests indicate that the modified fuzing system will operate with the present system for controlling the terminal trajectory of the missile.

(c) Explosive train safety tests and explosive train reliability tests were conducted with service loaded "LOON" warheads. These tests were conducted at the U. S. Army Sierra Ordnance Depot, Herlong, California. Five T74E3 fuzes

were modified to permit firing of the detonator in the unarmed condition. A fuze was installed in the service loaded warhead and the detonator fired from a remote barricade. A special fuze-removing tool controlled from the barricade permitted removal of the fuze from the warhead for examination. In all cases the resulting explosion was limited to the detonator only. Visual inspection revealed no damage to the warhead fuze cavity liner. Five samples of the fuze modified to permit arming by lanyard from the firing barricade were used to detonate five service-loaded warheads. In all cases the fuze initiated a high-order detonation of the warhead.

(d) Inertia actuation tests and vibration tests were performed on the T6 and T9 switches. Vibration tests were performed to determine resonances and the characteristics of vibration that could cause actuation. Vibration tests on the switches failed to cause actuations. Centrifuge, air gun and drop tests were also conducted to determine minimum firing accelerations.

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At the request of the Bureau of Ordnance, the fuzing system for the missile "LOON" (JB-2) has been evaluated. It was requested that, in view of the urgency of the program, the prospective immediate use of the missile, and the limited number of missiles and fuzes available, emphasis be placed first on safety and second on operability. The evaluation program was conducted under Task NOL-Re2b-30-1-51, Problem 3. In a letter to the Bureau of Ordnance of 10 April 1951, the Laboratory recommended the use of the "LOON" fuzing system with certain modifications. Test results and recommended changes in the fuzing system are presented in this report. The opinions and judgments expressed are those of the Technical Evaluation Department.

EDWARD L. WOODYARD
Captain, USN
Commander

R. E. HIGHTOWER
By direction

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EVALUATION OF THE FUZING SYSTEM FOR THE MISSILE "LOON" (JB-2)

INTRODUCTION

1. The Naval Ordnance Laboratory has conducted a limited evaluation program on the fuzing system of the missile "LOON" for safety and operability as an item of shipboard ordnance, as requested by reference (a). This fuzing system was designed and manufactured for a U. S. version of the German V-1 guided missile. The missile was designated the "JB-2 Bomb" by the Army Air Force, and the "LOON" by the Navy Bureau of Aeronautics. BuAer has further designated the missile as the LTV-N-2 (Launcher Test Vehicle N-2).

2. The fuzing components consist of the following.

Athwartship Mechanical Impact Fuze T84E series
Athwartship Electrical Contact Fuze T74E series
Nose Contact Switch T8
Inertia Switch T9

The T84E series comprises the T84E1, T84E2, T84E3, and T84E4. The T74E series comprises the T74E1, T74E2, T74E3, and T74E4. In all of these the final number indicates the arming range as follows:

1 - 4 to 5 miles
2 - 12 to 15 miles
3 - 25 to 30 miles
4 - 40 to 50 miles

The different arming distances are provided by different gear ratios in the arming systems. Fuzes of the same series are otherwise identical. Fuzes provided for these tests were the T84E3 mechanical fuze and the T74E3 electrical fuze. Detailed descriptions of these components are included in Part 7, Chapter 21, Section 5 of reference (b).

3. The T84E series is a long delay air-arming mechanical fuze actuated by an inertia weight and tapered firing pin housing so arranged that slight sideways impact after arming will release a cocked firing pin. (The explosive train in the mechanical fuze is in permanent alignment.) The T74E series is a long delay air-arming, electrical fuze. The air vane, through the gear train and arming shaft, turns a plastic rotor (which contains an electrical detonator M36) one half

turn to line up the detonator with the explosive lead to the booster, and to connect the detonator's electrical leads to the ends of the firing circuit leads. This action, however, does not fire the fuze, as will be explained later. In this position a detent in the rotor snaps into a hole in the rotor housing, locking the rotor in place and disengaging it from the arming shaft. The T74E3 fuze is shown in figures 3 and 4. The air vanes of both the mechanical and the electrical fuzes are prevented from rotating until the missile is in flight by arming wires which pull free at the end of the launching phase. The detonator used in the T74E3 fuze is the M36. The upper charge is basically mercury fulminate, the intermediate charge is lead azide and the lower charge is PETN. The detonator cup is gilding metal.

4. The T9 inertia switch incorporates a universal pivot-mounted inertia weight having a polished concave face against which a polished hemisphere bears to hold the weight in position. The hemisphere is held against the concave face by a spring loaded contact bar. Tension on the spring is preset to require an acceleration of ten g normal to the pivot shaft to topple the weight. When this occurs the contact bar rotates under the spring load and completes the electrical circuit across the contacts. The switch is insensitive to force in the direction which increases the pressure of the hemisphere against the concave face of the inertia weight. It is bracket-mounted on the forward warhead bulkhead in a position such that the acceleration forces due to launching act in the direction to which it is insensitive. The inertia switch assembly consists of the inertia switch and a two microfarad condenser connected to a terminal board, all mounted on the inertia switch mounting bracket. The terminal board provides binding posts for connecting the other components of the fuzing system. The purpose of the condenser is to by-pass any voltage pulse which might be induced in the leads running aft to the Veeder-Root counter. The nose switch is a simple device having a coil spring mounted on a round plastic base and a brass shaft mounted co-axially with, but insulated from the spring. The switch is mounted in the forward part of the missile nose cone. On impact, the shaft is either crushed or bent so that it makes contact with the spring, and closes the circuit.

5. Although not considered an ordnance component, the "Veeder-Root" counter has one set of contacts which form a part of the electrical firing circuits. The counter is driven by a solenoid and ratchet arrangement powered by pulses from the missile electric power supply. The pulse rate is determined by the speed of an air-screw in the nose of the missile which drives a worm gear having a contact bar which closes the circuit once each revolution. The counter and air-screw combination is calibrated in air miles. The counter has two

sets of contacts each of which can be independently set to close after a preselected number of air miles travel. A three-digit set is used to limit missile flight in case command control is lost. It is usually set to initiate wing blow-off and dive the missile at five to ten miles beyond the target distance. A two-digit set is used as an additional safety device in the electrical firing circuit. It is usually set to close the electrical circuit to the battery at the nominal arming distance of the electric fuze. Once these contacts close, their driving arrangement is disengaged from the drive shaft so that they will remain closed for the duration of the flight.

6. Figure 8 shows the original circuit for the electrical components of the fuzing system. As can be seen from the diagram, at least three switches must close before the electrical fuze will fire. Two of these, the Veeder-Root counter and the fuze arming switch, are safety features and are closed by air travel. After these close, the weapon is fully armed and the warhead will be exploded upon closure by impact of the nose switch and/or the inertia switch.

7. Figure 8 shows the modified circuit for the electrical components. The modifications are discussed in paragraphs 9 and 13 following.

8. Full scale field tests were conducted at the U. S. Naval Air Missile Test Center (NAMTC), Point Mugu, California. The tests were conducted by participating in projects "LOON" and Derby (Trounce). The latter project is concerned with launching and controlling the missile from a surfaced submarine. Flight tests were scheduled in which the fuze tests were made the secondary objective without seriously interfering with the primary objective which provided the basis for authority to expend the missile. The proposed schedule included telemetered tests to be conducted to determine operating points of the arming devices and as a final check on the safety of the fuzing system before a service-condition test (all components live-loaded) was made.

FIELD TESTS

Fuzing System Modifications

9. The mechanical fuze T84E series was declared unsafe for Naval use, and will be discussed in paragraph 20. As a substitute for this component, it was decided to use an additional electrical fuze of the T74E series. The T74E series and the T84E series have the same external dimensions, which allowed the substitution to be readily made. The two electrical fuzes were connected in parallel as shown in figure 8.

10. To determine the degree of arming (that is, the position of the detonator in the rotor with respect to the explosive lead), six T74E3 fuzes were inerted and modified as follows: A small ten thousand ohm potentiometer was installed in the space normally occupied by the booster pellet and its shaft was mechanically connected to the fuze rotor. A shorting wire was connected across the detonator terminals on the rotor. The two-conductor firing lead was replaced by a five-conductor cable, three conductors of which were connected to the potentiometer, the other two being connected in place of the normal leads to the terminals which contact the detonator leads in the armed position. A calibration curve was prepared for each fuze showing degrees of rotation and revolutions of the arming vanes versus resistance from one end terminal of the potentiometer to its movable arm.

11. At the NAMTC, due to a delay in the delivery of the modified fuzes, it was necessary to inert two additional T74E3 fuzes for the first flight test. A shorting wire was connected across the detonator terminals but no position indicating potentiometers were installed. The fuzes, switches T8 and T9, the arming switch of the Veeder-Root counter and the air-log pulse switch were each connected, through proper voltage dividers and a battery, to separate channels of a six channel AN/AKT-10 telemetering transmitter installed in the nose of the missile. As a secondary means of monitoring the actuation of the fuzing system components, red smoke flares were connected to the fuzes and to the T8 and T9 switches so that closure of the circuit through any of these components would fire one of the flares. The flares for the fuzes were installed on the respective wingtips, the nose switch flare was installed on the under part of the nose cone, and the inertia switch flare was installed on the under part of the tail section. Previous tests at NAMTC had shown that with the flares so located, observers in chase planes could reliably identify the particular flares as they fired. This secondary monitoring system provided insurance against losing all data in case of telemetering system failure, and also provided an independent record against which the telemetering record could be checked. The oral reports of the chase plane observers are recorded for this purpose. Flare and telemetering connections for this test are shown in figure 9.

12. For the second flight test a similar system was used. The modified fuzes with potentiometers were connected as shown in figure 10. This connection provided a recorded signal for the fuze monitoring channels on which the deflection from zero position was proportional to the degree of arming up to the instant of complete arming. Complete arming was indicated by a sharp increase to full deflection.

13. Certain modifications in addition to the elimination of the mechanical fuze T84E series were found necessary as follows:

a. In connection with the substitution of an additional electrical fuze for the mechanical fuze, fairing conduit for the electrical leads was installed on the warhead to the port fuze cavity. This necessitated drilling holes in the aluminum warhead encasement for eight self-tapping, #8 by 3/8 inch mounting screws. On the explosive-loaded warhead this was done with a hand powered drill provided with a stop to limit the depth of the hole to 1/4 inch in the 3/8 inch thick encasement.

b. The nose section of the missile is regularly attached to the warhead by eight 3/8 inch NF machine bolts which thread into tapped holes in the warhead nose ring. During several tests previously conducted by the NAMTC, the nose section had separated from the missile at or shortly after wing blow-off. To prevent a recurrence of this break-up, the number of attaching bolts was doubled, eight additional holes being drilled and tapped midway between the existing holes in the warhead nose ring.

c. The present system of controlling the end trajectory of the missile provides for diving the entire fuselage into the target by blowing off the wings, stopping the pulse jet engine and removing the forces which control the tail surfaces so they will assume a neutral position. The trajectory of the fuselage then approximates that of a free falling bomb. One wing is blown off a fraction of a second after the other to give the fuselage an initial spin to improve the consistency of the trajectory. Previous tests by the NAMTC have shown that wing blow-off and/or the displacement of components due to spin usually result in the missile power supply battery being shorted. To prevent the live-loaded missile from becoming a dud from this cause, a separate 22.5 volt dry battery was provided as a power supply for the fuzing system. It was mounted in a special bracket on the under side of the inertia switch mounting bracket and was connected as shown in figure 8.

d. The electrical fuzes were designed to be used in the starboard fuze cavity, and the arming wire angle bracket is located on the fuze head flange in a position which properly aligns it with the starboard arming wire attached to the launching sled. The fuze must be oriented so the electrical leads line up with the fairing conduit. To adapt the fuze for use in the port cavity (where it replaced the mechanical fuze), the angle bracket was relocated to obtain proper alignment with the port arming wire. This required drilling and tapping two new holes for the #6-32 angle bracket mounting screws.

Results From Flight Tests

14. The first flight test was conducted on 7 December 1950, from the NAMTC shore-mounted, short-length launcher. During the launching phase the missile went into a slow left roll due apparently to some misalignment in the "Jato" sled launching unit. At the end of the launching phase ("Jato" burn-out) the sled detached itself and fell away in a normal manner, but the missile had rolled so far left (wings about 70 degrees from horizontal) that the autopilot was unable to assume control and correct the flight attitude. The missile continued to roll left and lost altitude quite slowly, making a flat dive into the sea in a completely inverted position, 8.82 seconds after launching and at a point roughly a thousand yards from the launcher. This was too short a flight to give any information on fuze or Veeder-Root counter arming, but the telemetering record and the observance that no smoke flares fired showed that the nose switch T8 and the inertia switch T9 successfully resisted the forces of launching.

15. The second flight test was conducted on 15 December 1950 from the same launcher. The launching and flight were normal and the test was considered successful in all respects. Figure 1 is a photograph of this missile during the launching phase. Figure 11 shows the telemetered record of the Veeder-Root counter and the two fuzes, in foreshortened form. The information obtained from these curves and its interpretation is as follows:

a. The Veeder-Root counter arming switch closed 5 minutes 44.6 seconds after launching. The missile speed during its climb to its maximum altitude of 4700 feet (altitude control had been preset to 5,000 ft) averaged about 220 knots ("Indicated Air Speed", as reported by the chase plane pilots). Thus the missile had traveled approximately 24.1 air miles at V-R counter arming switch closure, which is within reasonable accuracy of the preset distance of 25.3 miles.

b. The port fuze rotor turned smoothly into the armed position, arming the fuze after 7 minutes 52.6 seconds of flight. The firing of the port wingtip smoke flare reported by the chase plane observers corresponds with the telemetered record. The distance traveled by the missile at this time was approximately 33 miles as determined by the missile tracking stations. The published information (reference (b)) gives the arming distance of the T74E3 fuze as 25 to 30 miles.

c. The starboard fuze rotor turned smoothly into the armed position arming the fuze and firing the starboard wingtip

smoke flare after 8 minutes 12.4 seconds of flight. The flight distance at this time as determined by the missile tracking stations was approximately 35 miles, again considerably greater than the published information.

d. Shortly after the starboard fuze armed, the leads to one or possibly both of the smoke flares became partially shorted. All telemetered signals indicated nearly zero voltage, showing that the resistance of the short circuit was low compared to the resistance of the voltage dividers for the telemeter input signals. However, the resistance must have been sufficiently high to prevent excessive current drain from the battery as the recorded signals returned to nearly normal deflection immediately when the short was removed by wing blow-off. From this it appears that even during the period of the partial short circuit there was sufficient voltage on the circuit to have fired the respective smoke flares, had either the inertia switch or the nose switch closed.

e. The wing blow-off system functioned on command from one of the tracking stations after 11 minutes 49.5 seconds of flight. The missile dove into the sea 12 minutes 8.4 seconds after launching at a position about 58 miles from the launching site as determined by the tracking stations.

f. The recorded telemetered signals and non-actuation of the forward and after flares showed that the nose switch T8 and the inertia switch T9 successfully withstood the forces of launching, missile flight, wing blow-off, and terminal dive.

16. The third flight test was also conducted on 15 December, after the previously described test indicated proper functioning of all components. The missile, with a service loaded warhead and live fuzes, was launched from a surfaced submarine (see Figure 2) at a position approximately five miles off-shore from the NAMTC launching site. The launching, flight, and terminal dive were all normal as reported by observers. Wing blow-off occurred on command and the missile dove into the sea at a position approximately 46.5 miles from the launching point. At water impact the warhead exploded as expected, creating a water spout of impressive proportions as reported by observers in the chase planes and in a stand-by control plane located nearby at approximately 8,000 ft altitude. All reports indicate that the warhead explosion was of a high order.

Safety and Reliability Tests with Service Loaded Warheads

17. Field tests were conducted to determine the following:

a. The ability of the fuze to confine the explosion of the detonator without damage to the warhead fuze cavity liner when the detonator is initiated with the fuze in the unarmed condition.

b. The reliability of the fuze in initiating a high order explosion of the warhead when properly armed and fired.

For the explosive train safety test five fuzes were modified so that the detonator was connected to the fuze leads with the rotor in the unarmed position. For the explosive train reliability tests, five fuzes were modified as follows so that they could be armed by lanyard. The arming shaft, the gear train assembly and the air vane assembly (figure 4) were removed. A new arming shaft was installed which had the same diameter as the original but was of sufficiently greater length to extend approximately an inch beyond the fuze head, which was drilled out to accommodate the extended shaft. The extended part of the shaft was provided with a spiral spring, a lock pin and stops so that withdrawal of the lock-pin by lanyard pull allowed the spring to rotate the arming shaft and the detonator rotor into the armed position. No change was made in the explosive train of these fuzes.

18. The tests were conducted in the Explosive Area of the U. S. Army Sierra Ordnance Depot, Herlong, California. This area is located in rolling foothills approximately ten miles (air line distance) north of the main depot area. A comparatively level site, free of large stones and approximately two thousand feet from the firing barricade was selected. The soil was heavy, sand loam containing a few small stones (up to two inches in diameter) and was thoroughly and uniformly damp. No freezing had taken place below the two inch level and even the surface had completely thawed each day by the time the first test was conducted. Three lines of rubber-covered, two-conductor blasting cable (about No. 18 copper wire) were laid on the surface from the test site to the firing barricade. A plunger type blasting machine was provided as the energy source for all explosive firing.

19. The warhead was set on its large diameter end on bare earth at a position at least thirty feet from the nearest existing crater. The fuze for the firing train safety test was installed and a special solid-fuel-rocket-powered fuze-removing tool was loaded and mounted on the fuze. The fuze and the fuze-removing tool were then connected to the firing circuits. The connected fuze was then checked for continuity and fired. After a waiting period of approximately five minutes, the fuze-removing tool was fired. After an additional waiting period, the fired fuze was recovered and inspected.

In all cases only the detonator fired. The fuze with the fired detonator was characterized by a bulged fuze body. Inspection of the fuze cavity liner revealed no damage either from the fired detonator or the removal of the fuze by the rocket wrench. In some cases, two safety tests were conducted in the same fuze cavity. For the explosive train reliability tests the fuzes were installed in the service loaded warheads in the unarmed condition, then the firing leads were checked and connected to the fuze. The last operation was to fasten the arming lanyard to the arming pin. At the firing barricade the firing circuit was checked while the arming lanyard was being pulled to assure that the fuze was armed by the spring arming system. The fuze and warhead were then fired. All five warheads were detonated high order, with few recoverable fragments. The recovered fragments were approximately uniform in size with maximum dimensions of about 12 inches and indicated extremely high temperatures; that is, the aluminum apparently melted and fused together. The craters averaged approximately 7-1/2 feet in depth, and ranged from 24 to 27 feet in diameter.

LABORATORY EVALUATION TESTS

20. At the beginning of the evaluation program the mechanical fuze T84E3 was declared to be unsafe for shipboard use. An examination of the drawings and subsequently of the fuze showed that the fuze contained no detonator safety feature. The sensitive element which contains lead azide housed in gilding metal is in permanent alignment with a cocked firing pin, tetryl lead and booster. Consequently the laboratory evaluation program is concerned only with the electrical T74E3 fuze.

Transportation Vibration Tests

21. Ten fuzes were subjected to the Military Standard Transportation Vibration Test for Use in Development of Fuzes (MIL-STD-303). Visual inspection of the fuzes after the first phase of the vibration test (packed as for shipment) showed no damage. The fuzes were then rigidly mounted in fixtures and given the standard vibration tests. Inspection revealed the following changes:

a. One booster cup came unsealed.

b. One fuze sleeve came unsealed from the fuze head. (The booster cup and fuze sleeve are sealed by using Petman cement).

c. The small locating screw (figure 4) which holds the gear housing to the locating disc inside the spacer was loosened

in three of the fuzes. All detonator bridge wires were continuous after the test. In general the ten samples showed no unreasonable wear or no serious damage, and therefore were safe and operable.

Jumble Tests

22. Ten samples were subjected to jumble tests in the NOL 24" Jumble Box. The fuzes suffered considerable damage during this test and all the fuzes were damaged similarly. The booster pellets broke up and tetryl was spread throughout the fuzes. In seven units the booster cup came unsealed from the body. All detonator leads broke off at the base of the detonator due to motion of the detonator in its cavity. In six of the units the aluminum locating disc on which the gear train is mounted, came completely loose and fell down inside the cylindrical spacer. In the other units the locating disc was loose but still in place. The three Philips-head screws holding the rotor housing to the metal spacer came out in eight of the ten samples. With the locating clip out of a fuze which is in either of the two conditions described above (aluminum locating disc freed from gear train mount or rotor housing freed from cylindrical spacer) there is no positive locking of the rotor with respect to the lead disc. In this condition there is a possibility of alignment between the detonator and lead. The locating clip came out of two fuzes in which the rotor housing was freed. In spite of this condition the fuzes tended to hold together, and none were in an armed condition at the end of the test. The lug on the rotor housing used for locating the tetryl lead disc was broken off in three of the fuzes. However the rotor housing held together until the fuze was disassembled. Had this broken guide lug not held in place there would be no positive locking of the lead disc with the rotor housing, and there is a possibility the lead could align itself with the detonator. None of the fuzes were operable as a result of the jumble test. All the fuzes could be considered hazardous because of the spreading of tetryl throughout the threads and gear train.

Jolt Tests

23. Seven fuzes were allocated to the Military Standard Jolt Test for Use in Development of Fuzes (MIL-STD-300). Initially four samples were tested. The boosters in these samples failed to maintain their pellet form, but crumbled to a fine powdery dust; consequently this tetryl dust spread in varying amounts throughout the fuze. Considerable tetryl was found even in the gear train housing. Approximately half the tetryl came out of the booster cup. As a result of this, new pellets were made and installed in all the remaining fuzes. The new booster was

made up of two small pellets in place of the larger one. Three more units with new boosters were given the Military Standard Jolt Test. These boosters were in good condition at the end of the test and there was no tetryl dust inside the fuzes. Of the original four fuzes jolted, three booster cups came unsealed. None of the last three fuzes which were resealed with glyptal came unsealed. Due to the vertical motion of the detonator in the rotor, lead wires broke off at the base of the detonator in five out of the seven fuzes. The detonators were displaced about 1/16th inch from their normal positions, thus increasing the spacing between the detonator and lead disc (figure 5). In five of seven fuzes the vane safety wires came off. The locating clip did not come out in any of the fuzes. The rotor was in good condition; however, the bakelite rotor housing was broken in two of the fuzes. In two of the fuzes the aluminum locating disc (figure 4) on which the gear train is mounted, came loose and fell down inside the cylindrical spacer. In four of the fuzes this disc was being held by a few threads of the locating screw. In one unit the three Philips-head screws that hold the rotor housing to the cylindrical spacer came out. Firing leads connecting the spring contacts in the rotor housing were also broken off in this fuze. Of the seven fuzes jolted, one fuze would have been operable. The remaining six would not have been operable either due to broken connecting leads or the broken rotor housing. Bridge wires on the undamaged detonators were continuous.

Forty Foot Drop Test

24. Forty Foot Drop Tests were conducted on five samples. All drop orientations were made to conform with the specifications of the Military Standard Forty Foot Drop Test for Use in Development of Fuzes. The test vehicle used was an inert loaded "LOON" warhead. All live fuzes were used. In the horizontal orientation the drop was made directly on the fuze. This fuze was recovered by cutting it away from the warhead. The arming shaft had been pressed with considerable force against the lead disc, but there were no indications of unsafety. All explosive components appeared to be normal. The fuze which was used in the drop with the warhead base down could not be inspected. After the drop the fuze seat liner was found to be displaced downward at an angle of about 30° with the horizontal. Inspection of the warhead after the fuze had been cut away revealed imperfections in the loading. There was cavitation in the inert material causing the load to shift thus tending to force the fuze seat liner toward the base of the warhead. The indentations on the fuze seat liner were such that the fuze could not be safely removed. This was not considered to be expedient since the condition was not due to the fuze irregularities but to imperfections in the vehicle. The remaining three fuzes were undamaged

and there was no compromise to safety in any manner. All inspected bridge wires were continuous.

Salt Spray Fuze Test

25. Five samples were allocated for the Standard Salt Spray Fuze Test. Two fuzes were mounted with vanes up, two with vanes down, and one horizontal. Following the salt spray test, two of the fuzes, one tested with vanes up and one tested with vanes down, were subjected to a temperature of -22°C for a period of ninety-two hours. The other three were allowed to dry at ambient temperatures. The cold fuzes both had a small amount of salt on the inside surface of the fuze housing. There was no corrosion inside the fuze mounted with the vanes down. The fuze mounted with the vanes up was considerably corroded around the gear train housing, and in the gear train. The three fuzes kept at ambient temperature required very small torques to rotate the arming vanes. The fuze mounted with the vanes down was in good condition and showed very little corrosion. The fuze which had been mounted in the horizontal position had a small quantity of salt on the rotor, in the booster cup threads, in the gear train, and on the lead disc. The fuze which had been mounted with vanes up was considerably corroded between the gear train housing and top of the fuze. The lead disc and shaft were also corroded.

Temperature, Humidity, and Air Arming Tests

26. Six samples were subjected to the Military Standard Temperature and Humidity Test for Use in Development of Fuzes. Boosters were then removed and inspected. Two of the boosters had a tendency to crumble when they were removed. Three of the fuzes were armed and fired without inspection. The fuzes were armed by an air stream. The velocity of the air was such that the fuzes armed in from three to five minutes. One of these fuzes was armed and fired at ambient temperatures, one at 160°F and the other at -65°F. All the fuzes armed normally and fired high-order. Of the remaining three fuzes, one sample was broken down for inspection. There was some discoloration from the rotor on the lead disc; otherwise there were no indications of deterioration. The fuze was then reassembled complete with booster and armed. The detonator (M36) showed continuity after arming, but failed to fire. The remaining two fuzes were partially armed and then inspected, after which they were fully armed. The arming operation on these two fuzes was accomplished at -65°F and 160°F respectively. Previous to the arming of the fuze at -65°F, inspection revealed that the rotor was held tightly to the lead disc by a thick layer of wax which probably came from the rotor. However this condition did not interfere with the arming process, since both

fuzes armed satisfactorily. Of the last two fuzes the one at -65°F fired high-order. The detonator in the other fuze failed to fire although it showed continuity after arming. Four fuzes were modified to permit remote arming by lanyard. They were then fully loaded complete with boosters. Two of the fuzes were armed and fired at -65°F and two at 160°F. All the fuzes fired high-order.

Explosive Train Safety and Reliability

27. In the unarmed condition the detonator located in the rotor is positioned 180° from the tetryl lead located in the lead holder disc. This orientation positions the detonator a distance of .79 inches from the lead. Arming is accomplished when the arming shaft turns the rotor one half turn. The detonator blast hole is then in line with the tetryl lead. A measure of the safety and reliability of the fuze was made by conducting a Bruceton sequential test. An unsafe condition was believed to exist when the tetryl lead cup was compressed diametrically and pushed into the booster as shown in figure 7. In the normal condition the lead cup is approximately level with the lead disc. The reliability tests were in most cases conducted with live boosters, however a few were conducted with inert boosters. Figure 5 shows the effect on a booster of firing a detonator in an unreliable position. Lead discs from these tests are shown in figures 6 and 7. The Bruceton tests were run by using the shortest distance between the detonator and the tetryl lead as the variable tested; however, the results are presented as angular measurements for convenience. The 50% reliable and the 50% unsafe positions were determined from the Bruceton sequential test. The 50% reliable position is defined as the position where 50% of the tests will be expected to result in a high order detonation of the booster. The 50% unsafe position is defined as the position where 50% of the tests will be expected to result in the unsafe condition defined above. These tests indicate that the fuzes are expected to be 50% reliable when the distance between the detonator center and the lead center is 0.19 inches or at an angle of 28° from armed, with a standard deviation of .03 inches. The 50% unsafe position was found to be at a distance of 0.31 inches or 47° from the armed position, with a standard deviation of .01 inches. From this information the 99.9% reliability point was found to be 0.10 inches or 14° from completely armed, and the 0.1% unsafe position was determined as 0.34 inches or 51° from armed. The curves of figure 12, which were determined by a statistical analysis of the Bruceton test, indicate a measure of the reliability and unsafety of the fuze. It is obvious that the 99.9% reliability position and the 0.1% unsafe position cannot be accurately predicted since the sample size is small;

however, these calculations are the best estimate that may be obtained from the data. Referring to figure 12, it is seen that the 50% points of the reliability and the unsafety curves are about 20° apart. In view of this condition, the judgment of the unsafe position does not appear to be too severe, even though there was no visible rupture of the lead cup or burning of the tetryl.

LABORATORY EVALUATION TESTS ON T9 AND T8 SWITCHES

Centrifuge and Air Gun Tests on T9 Inertia Switch

28. Two switches were tested in the NOL medium speed centrifuge. When the switch was mounted in a position such that the inertia force corresponded to that which would act during launching of the missile, accelerations of 200 g (maximum applied) did not actuate the switch. Static firing tests were also conducted with the switch at different orientations with respect to the position described above, which is designated as the 0° position. The static actuating accelerations varied from approximately 9 g at orientations of ± 90° to approximately 24 g at ± 150°.

29. One T9 inertia switch was subjected to a series of successive single-phase 15" air gun shocks with the inertia force acting in the same direction as that experienced by the switch during launching. The peak launching acceleration of the missile is 10 g; however no switch closures were detected during air gun shocks up to 150 g. This switch was also subjected to a series of single-phase air gun shocks in order to obtain a comparison between the minimum acceleration required to actuate the switch under an air gun type shock and, that under a static force as indicated by the centrifuge tests. The inertia force was applied at -135°. The switch required a minimum acceleration of 29 g to close during the air gun tests as compared to 15 g during the centrifuge tests. The air gun acceleration-time curve increases from zero to peak acceleration in approximately five milliseconds, then decreases from peak to zero acceleration in about forty milliseconds.

Vibration Test on T9 Inertia Switch

30. The switch was mounted to a plate by the three mounting holes on the back of the switch mounting bracket. The plate was then mounted in a vertical position on an LAB vibrator. This is the normal mounting position of the switch on the warhead of the missile. In this orientation the pivot is parallel to the vibrator table. The switch was then subjected to vibrations of varying frequency, amplitude and direction to determine whether the switch could be made to actuate under vibrations. Starting at 600 cpm the frequency was increased in 300 cpm steps at three amplitudes .040, .060 and .080

inches double amplitude, in each of the three orthogonal directions and maintained momentarily at each frequency. The maximum frequency was 3600 cpm. When the direction of vibration was perpendicular to the pivot, double amplitudes of more than 0.25 inches were observed at the concave face of the pivot between the frequencies of 2800 and 3200 cpm; however the switch could not be made to actuate.

Vibration Tests on T8 Contact Switch

31. Vibration tests were performed on one sample of the T8 contact switch to determine resonances and the characteristics of vibration that would cause actuation. Actuation (closure) of the switch was determined by a thyratron indicator connected across the switch. The switch was rigidly mounted on the table of a vibration machine with the axis vertical and with the axis horizontal. Vibration was applied in the axial direction and in the cross-axial direction respectively. The rubber sheath was removed in order to observe the operation of the parts. Resonance of the mass-spring system occurred at 92 cps under axial vibration. A single amplitude of 0.008 inches in the forcing vibration produced a single amplitude of 3/16 inches at the end of the spring; however a single amplitude of about 0.5 inches would be necessary to cause actuation. The rubber sheath was then replaced and axial vibration again applied. With the sheath in place resonance occurred at 100 cps, but the damping had been so increased that a 0.0065 inches amplitude forcing vibration caused only 0.025 inches single amplitude at the end of the spring. No actuation occurred. When cross axial vibration was applied, with sheath in place, resonance occurred at 75 cps. A single amplitude of the forcing vibration of 0.020 inches produced a single amplitude of about 0.5 inches at the tip of the spring. The switch failed after a few seconds of this vibration. Actuation did not occur. The brass stem was broken in two at the shoulder of the plastic projection.

Air Gun Shock Tests of T8 Switch

32. Six samples were subjected to air gun shock tests to determine the minimum acceleration required to actuate the switches. Each switch was tested in two different positions.

a. One switch was mounted in a position such that the inertia force acted along the axis of the switch in a direction toward its base.

b. The other switch was mounted so that the inertia force would be transverse to the axis of the switch.

The minimum peak acceleration range for actuation was 225 to 300 g for switches mounted such that the inertia force was along the axis (position "a"). The range of minimum actuation acceleration for switches mounted in position "b" was 70 to 100 g. The general acceleration time curve pattern is described in paragraph 29.

Drop Test on T8 Switch

33. One switch was subjected to drop tester impact tests to determine the performance of the switch under shorter-duration impacts. The first series of drops were made using lead pads. The switch was first mounted such that the direction of the inertia force acted toward the base of the switch. The maximum impact was characterized by a velocity change of 17.0 ft per second with a peak acceleration of 450 g and a time duration of 3.5 milliseconds. The switch did not fire under the maximum impact. The switch was then mounted such that the inertia force was perpendicular to the axis of the switch. In this series of tests the switch did indicate closure. The minimum switch actuating shock was characterized by a velocity change of 8.2 feet per second, a peak acceleration of 110 g, and a time duration of 4.0 milliseconds. The second series of tests consisted of steel on steel impacts, and as before, the switch did not close when mounted such that the inertia force acted toward the base. The maximum impact under which the switch was tested was characterized by a velocity change of 13 feet per second and an average acceleration of 2300 g. The impact duration was 0.2 milliseconds. However, with the inertia force acting perpendicular to the axis of the switch, closures were recorded. The minimum shock required to actuate the switch in this position was characterized by a velocity change of 5.6 feet per second, an average acceleration of 750 g, and a time duration of 0.2 milliseconds.

CONCLUSIONS

34. a. The fuze appears to be safe and operable and in accordance with the criteria of reference (c), paragraph 3, as a result of the Military Standard Transportation Vibration Test.

b. Fuzes subjected to the Jolt and Jumble Tests were generally inoperable, and could be considered as unsafe to handle, as a result of the tetryl being spread throughout the fuze gear train. However, this condition was corrected in the jolt tests when new boosters were used. The condition which exists due to the locating disc falling into the cylindrical spacer could be conducive to a hazardous condition if the explosive train became aligned. As a result of breakdown and inspection of fuze samples from the jolt test, the fuzes tested

with the new boosters have met the requirements of reference (d), paragraph 3. The fuzes subjected to tests in the 24 inch jumble box were considerably damaged; however, no elements exploded or were in an armed condition after the test. Therefore, the fuze was judged to be reasonably safe.

c. All fuzes subjected to the Salt Spray Fuze Test appeared to be capable of performing their intended functions. The fuze was most vulnerable to corrosion when placed in a vertical position with vanes up.

d. Three of the fuzes from the 40 Foot Drop Tests were completely safe and operable. The fuze dropped in the horizontal position was not operable but there was no compromise to safety. The fifth fuze could not be safely inspected; however, there were no indications of detonation of any of the explosive elements. The fact that inspection was impossible was the result of an improperly loaded warhead. Samples from this test are judged to have met the criteria of reference (e), paragraph 3, for passing the Military Standard Forty Foot Drop Test.

e. Fuzes subjected to the temperature and humidity test showed no indications of unsafety. There was no malfunctioning of the arming system either at ambient temperatures or at the extreme temperatures of the JAN Cycle. From the six samples of this test, the explosive trains fired high order at ambient temperatures and at extreme temperatures, with two exceptions. One detonator failed at ambient temperature and one at 160°F. Failure of the detonator after temperature and humidity cycling was apparently the result of deterioration of the priming mixture which is basically mercury fulminate and is known to be susceptible to failure after surveillance testing. Reference (g) is a report which offers a possible explanation for detonator misfire even though the bridge wire is continuous. It advances the theory that the failures may be caused by voids around the bridge wire which are caused by excessive solvent in the explosive. The M36 detonator which is similar to the detonator described in reference (g) contains a priming mix of mercury fulminate milled in a solution of nitrostarch in butyl acetate. In addition the explosive increments are held in the detonator cup by a holder plug made of a molded phenolic material, which appears to be vulnerable to surveillance testing. There is a tendency for the boosters to crumble, which may contribute to an unsafe condition if fuzes have been stored for a long period of time and are then transported. Reference (f), paragraph 3, states that the fuzes must be safe and operable following this test. All the fuzes were judged to be safe, but two fuzes would not have been operable because of detonator failure. Tests

indicate that the explosive train (complete with boosters) will detonate high order at temperatures of -65°F and 160°F.

f. At the point of tangency between the detonator and lead (35° from armed) the reliability is 4%. The reliability increases to 95% when the detonator moves 15° closer to the armed position. In this position the detonator overlaps about 45% of the lead area. Thus it appears that adequate reliability can be expected when the detonator is in the completely armed position.

g. The 0.1% unsafe position was predicted to be 51° from armed. Since the completely unarmed position is 180° from armed, the fuze appears safe in this respect.

h. Fuze-to-warhead safety tests indicate that the "out-of-line" arrangement of the explosive train of the unarmed T74E3 fuze will reliably prevent explosion of the lead, booster and warhead in the event the detonator is initiated.

i. Explosive train reliability tests indicate that when properly armed and fired, the fuze will initiate a high order explosion of the warhead.

j. In field tests, two missiles were successfully air-launched. The nose switch T8 and the inertia switch T9 withstood the forces exerted by launching, flight, wing blow off, and terminal dive. The arming distance of the T74E3 electrical fuze is fifteen to twenty percent greater than indicated by the published data. These tests indicate that the modified fuzing system for the "LOON" is capable of detonating the warhead.

k. Laboratory shock tests on the T8 and T9 switches indicate that both switches will withstand the forces of launching.

l. Neither switch could be made to actuate at the vibration frequencies and amplitudes tested. Considerable amplitude was observed when the T8 switch was vibrated at its resonant frequency of 75 cps and with a forcing amplitude of 0.020 inches. The switch failed by the brass rod breaking in two at the shoulder of the plastic projection.

m. Two hundred and ninety T74E3 fuzes were renovated by replacing the boosters with the type described in paragraph 23. These fuzes were then shipped to the Naval Ammunition and Net Depot, East Long Beach, California.

RECOMMENDATIONS

35. The use of the "LOON" fuzing system with the following changes is recommended:

a. Omission of the existing T84E series mechanical fuzes.

b. If the present method of controlling the terminal trajectory (wing blow off) is used, it is recommended that the system described in the published information (reference (b)) be changed to the system shown in figure 8. This change consists of:

(1) Replacement of the T84E series mechanical fuze with a T74E series electrical fuze connected in parallel with the original T74E series electrical fuze (the T84E series is not recommended in any case).

(2) Isolation of the electrical fuzing system from the missile power supply by providing a separate battery for the fuzing system (see subparagraph 13c).

c. The following alterations of explosive components necessitated by the above changes and discussed in subparagraphs 13a, b, and d, be accomplished in an approved, explosive-work area before the components are issued for use:

(1) Drill holes in the warhead encasement for mounting the fairing conduit for the electrical leads for the port fuze.

(2) Drill and tap holes in the warhead nose-ring for doubling the number of attaching bolts for the nose section.

(3) Relocate the arming wire guide bracket on half of the existing T74E series electrical fuzes.

d. If eventually it should be decided to continue the use fo the "LOON" as an item of shipboard ordnance, it is suggested that a fuze redesign program be initiated to eliminate weaknesses in the present design. It is suggested that consideration be given to the design and development of self-contained fuzes (electrical and/or mechanical) for the missile "LOON", to eliminate the long, vulnerable electrical leads upon which the functioning of the present system depends. Such fuzes will be required upon approval of an improved method for controlling the terminal trajectory which is now under development at the NAMTC. This method consists of parting the warhead from the missile by the use of explosive bolts. The free-falling warhead has a more consistent trajectory than the wingless missiles. To be adaptable to this method, the fuzes should be

sensitive to impact shock from any direction, and should not depend upon the functioning of an external component for proper actuation.

REFERENCES

(a) BuOrd conf ltr Re2b-WFR/mjd S78-1(26) Serial 10382 of 28 July 1950 [NOL File NP51/S78-1(FM-687)]
(b) Ordnance Pamphlet 1644 (Vol. 2) of 28 May 1947
(c) Military Standard Transportation Vibration Test for Use in Development of Fuzes (MIL-STD-303)
(d) Military Standard Jolt Test for Use in Development of Fuzes (MIL-STD-300)
(e) Military Standard Forty Foot Drop Test for Use in Development of Fuzes (MIL-STD-302)
(f) Military Standard Temperature and Humidity Test for Use in Development of Fuzes (MIL-STD-304)
(g) Cannon Primers M113 (ND-24) Report No. 49-2 The Quality Control Surveillance Laboratory, U. S. Naval Ammunition and Net Depot, Seal Beach, Calif. of 28 Jan 1949

ILLUSTRATIONS

Figure 1. Missile During Launching Phase
Figure 2. Missile Launched from Surfaced Submarine
Figure 3. T74E3 Fuze
Figure 4. T74E3 Fuze (Exploded View)
Figure 5. (a) Rotor from Jolt Test
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Figure 6. Lead Discs from Safety and Reliability Tests
Figure 7. Lead Discs from Safety and Reliability Tests
Figure 8. Diagram of Original and Modified Firing Circuits
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Figure 10. Telemetering Connection No. 2
Figure 11. Curves from Telemetered Flight of 15 December 1950
Figure 12. Detonator Safety and Reliability Curves

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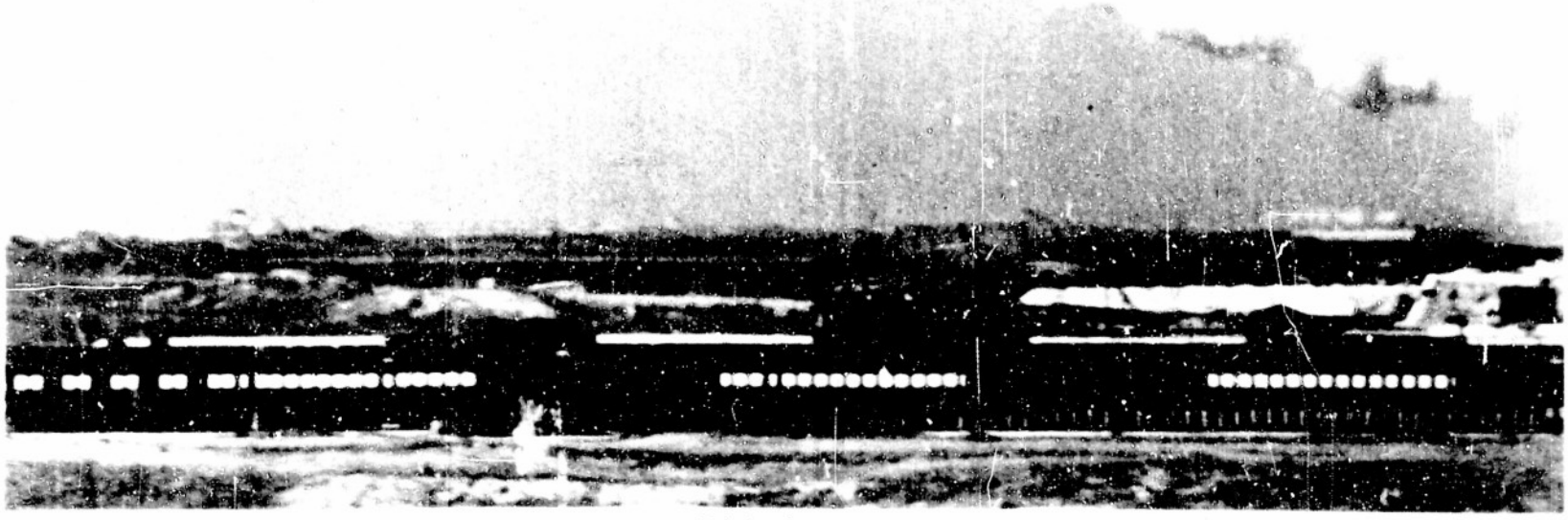

FIG. 1
MISSILE DURING LAUNCHING PHASE

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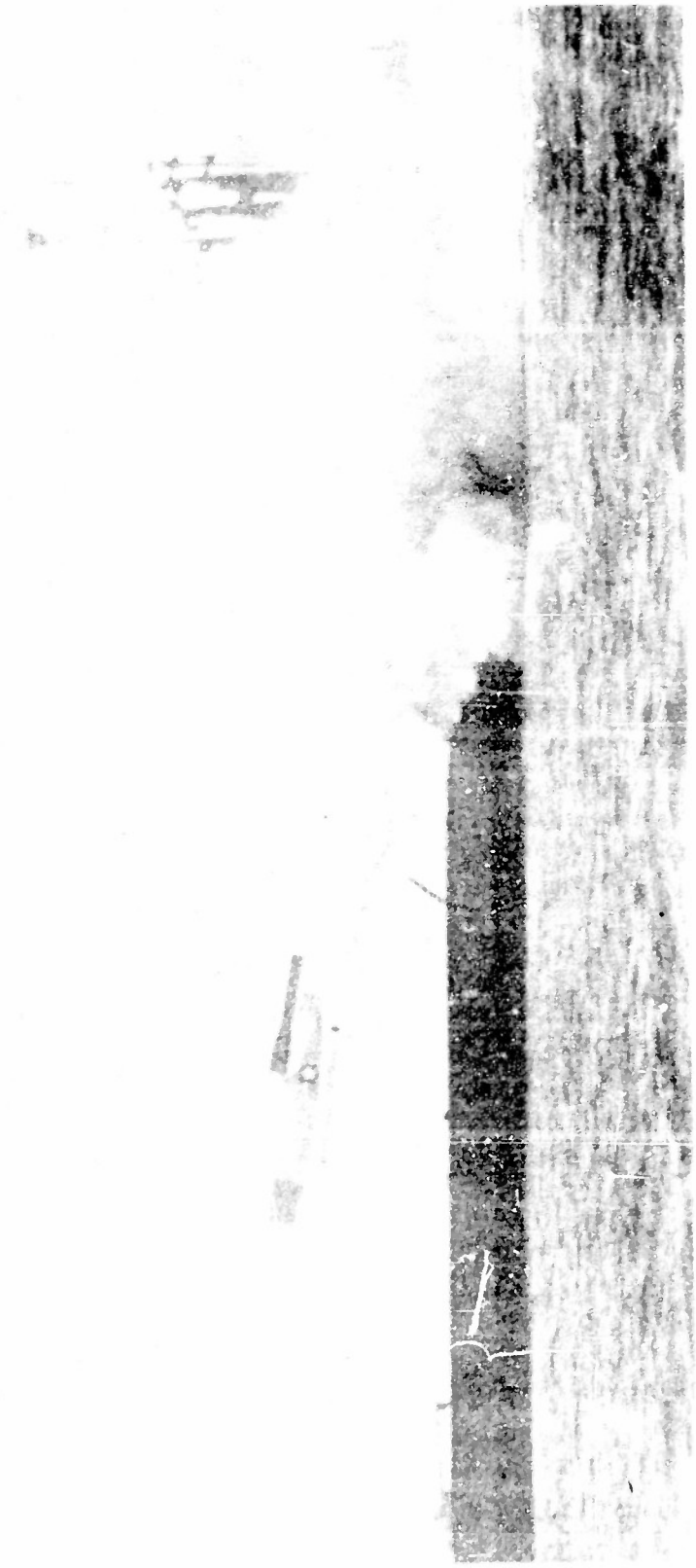


FIG. 2 MISSILE LAUNCHED FROM SURFACED SUBMARINE

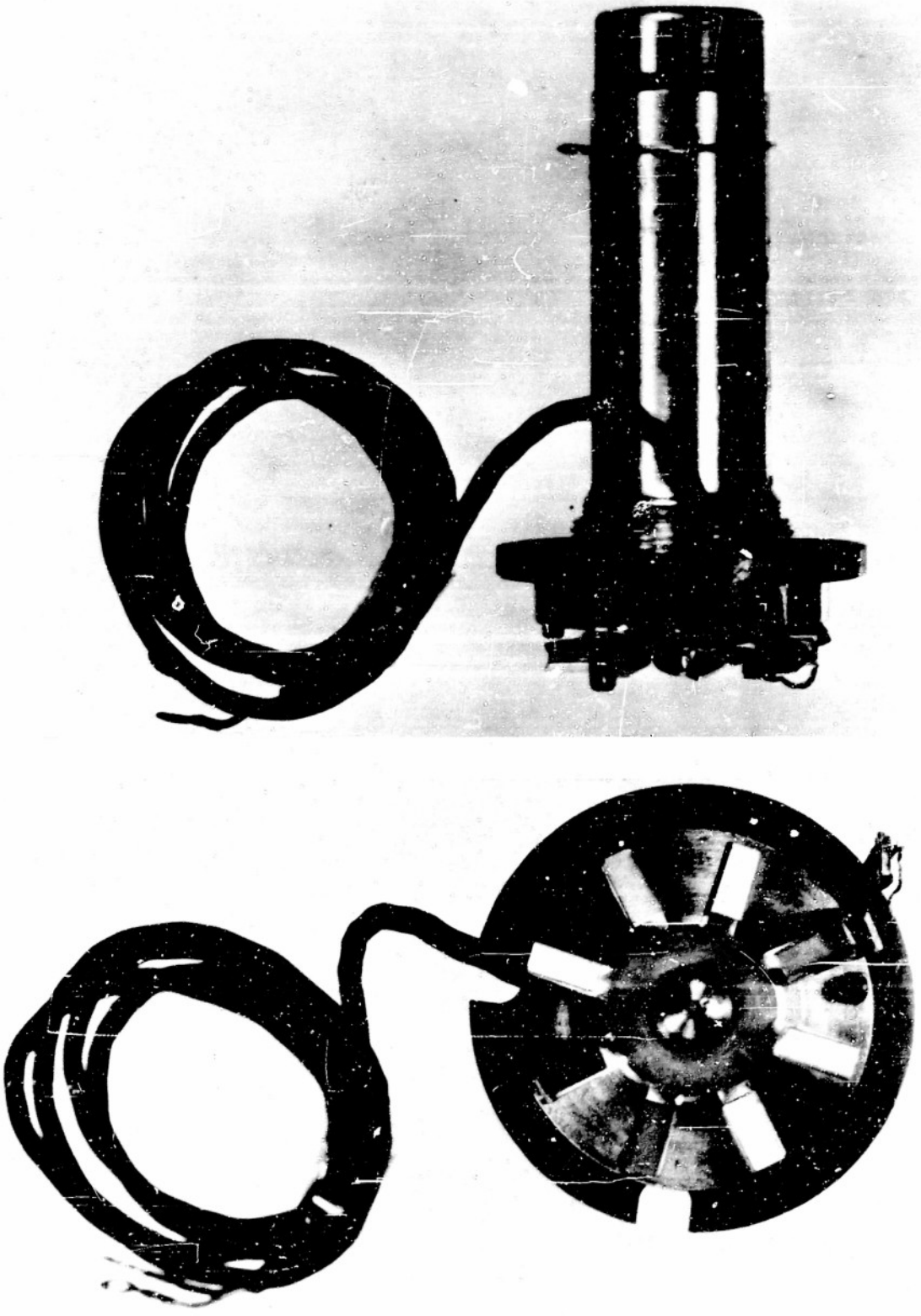


FIG. 3 T74E3 FUZE

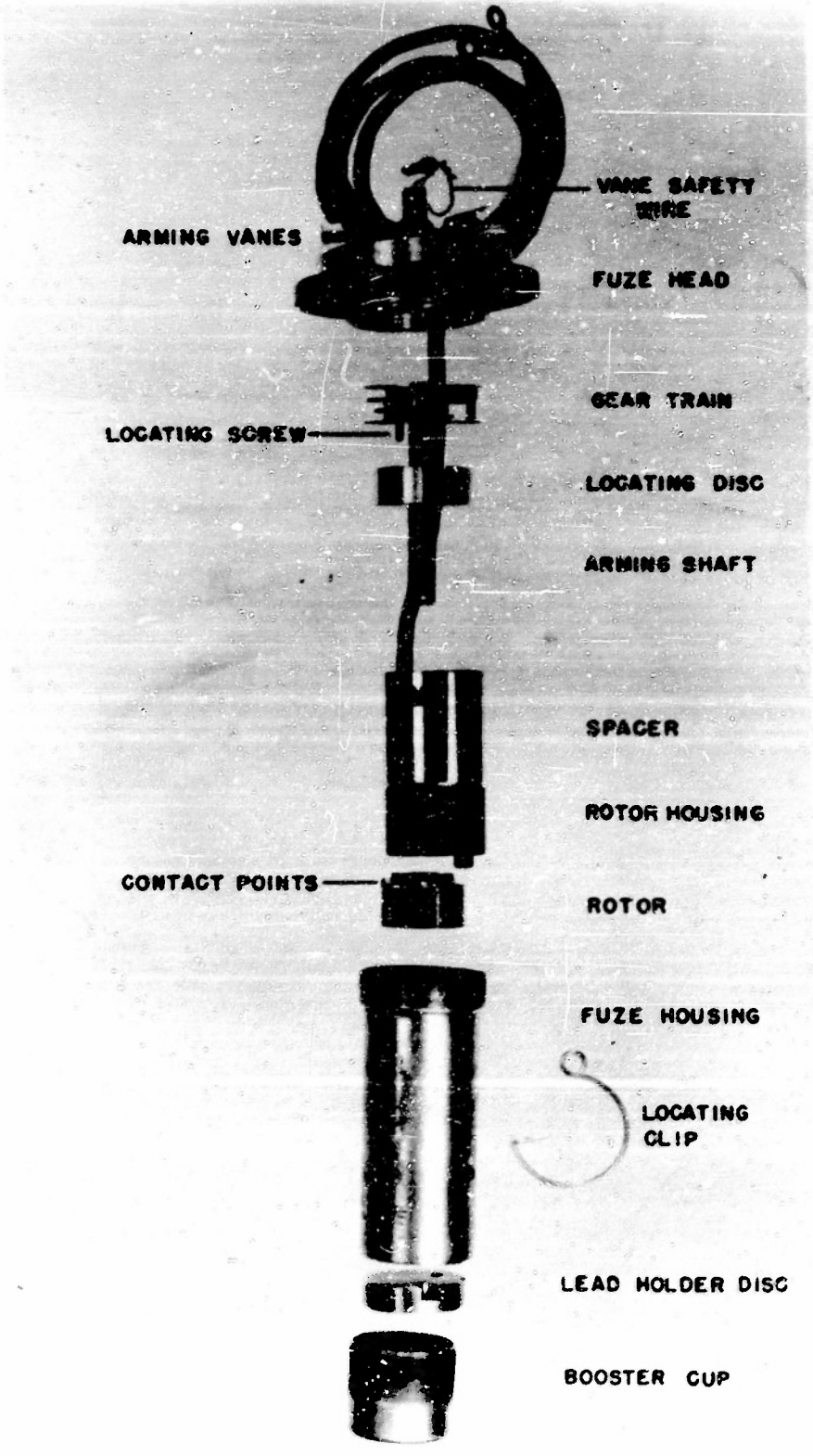
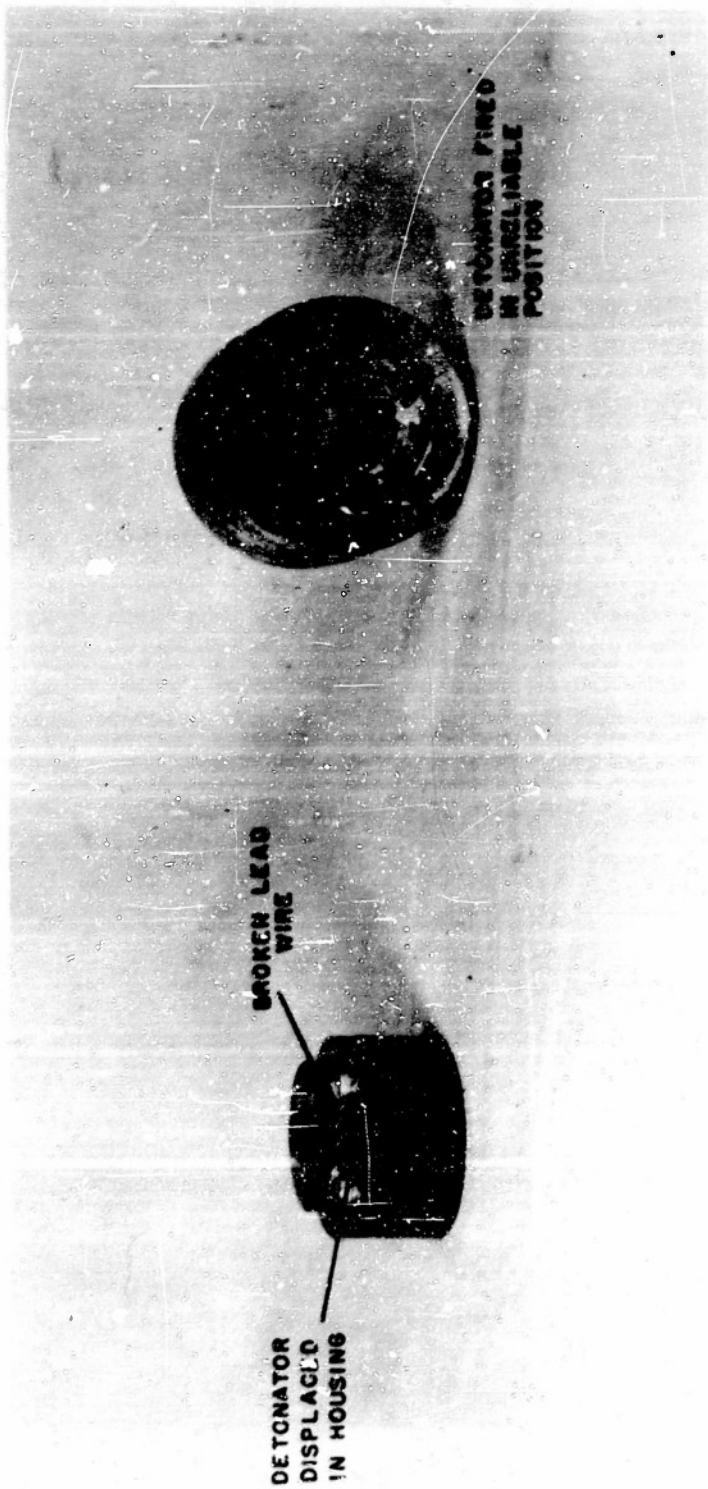


FIG. 4 T74E3 FUZE (EXPLODED VIEW)



(a) ROTOR FROM JOLT TEST

(b) BOOSTER

FIG. 5

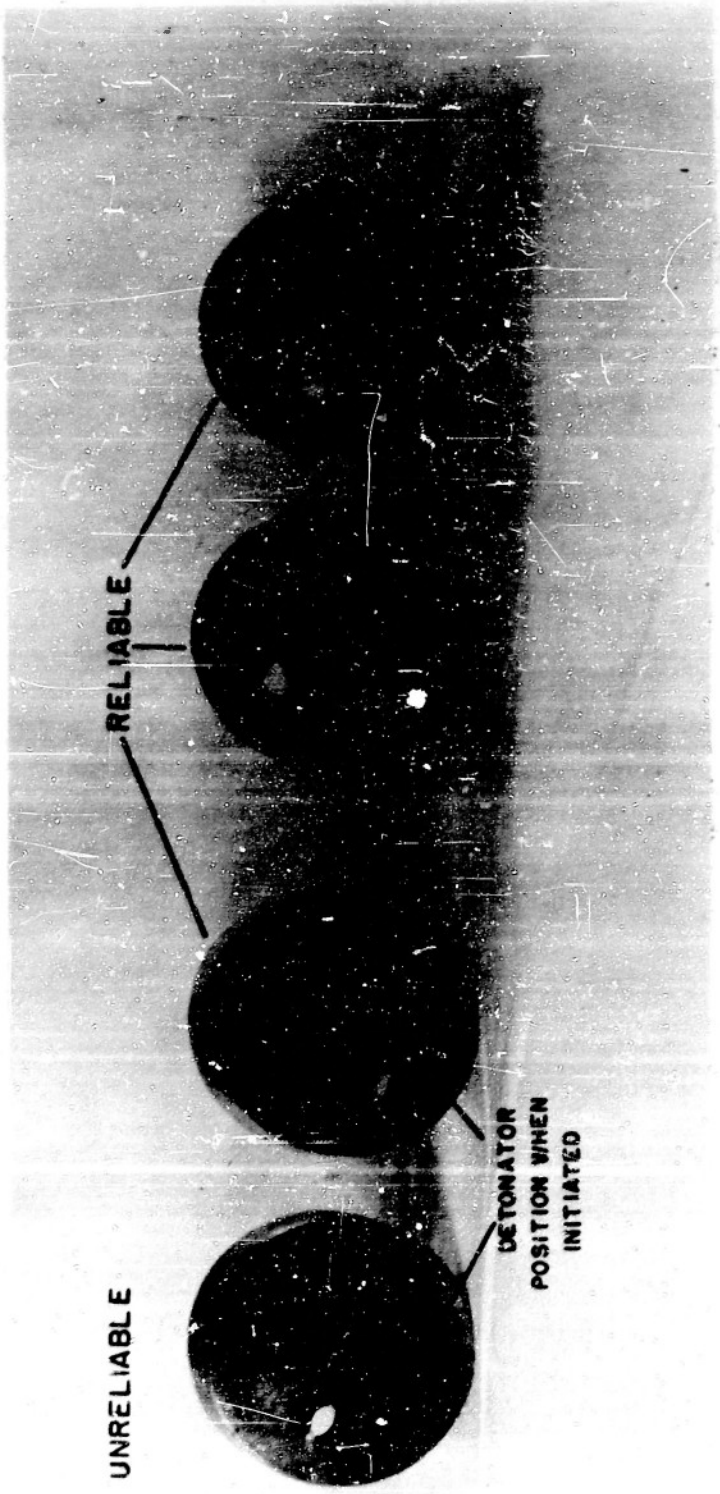


FIG. 6 LEAD DISCS FROM SAFETY AND RELIABILITY TESTS

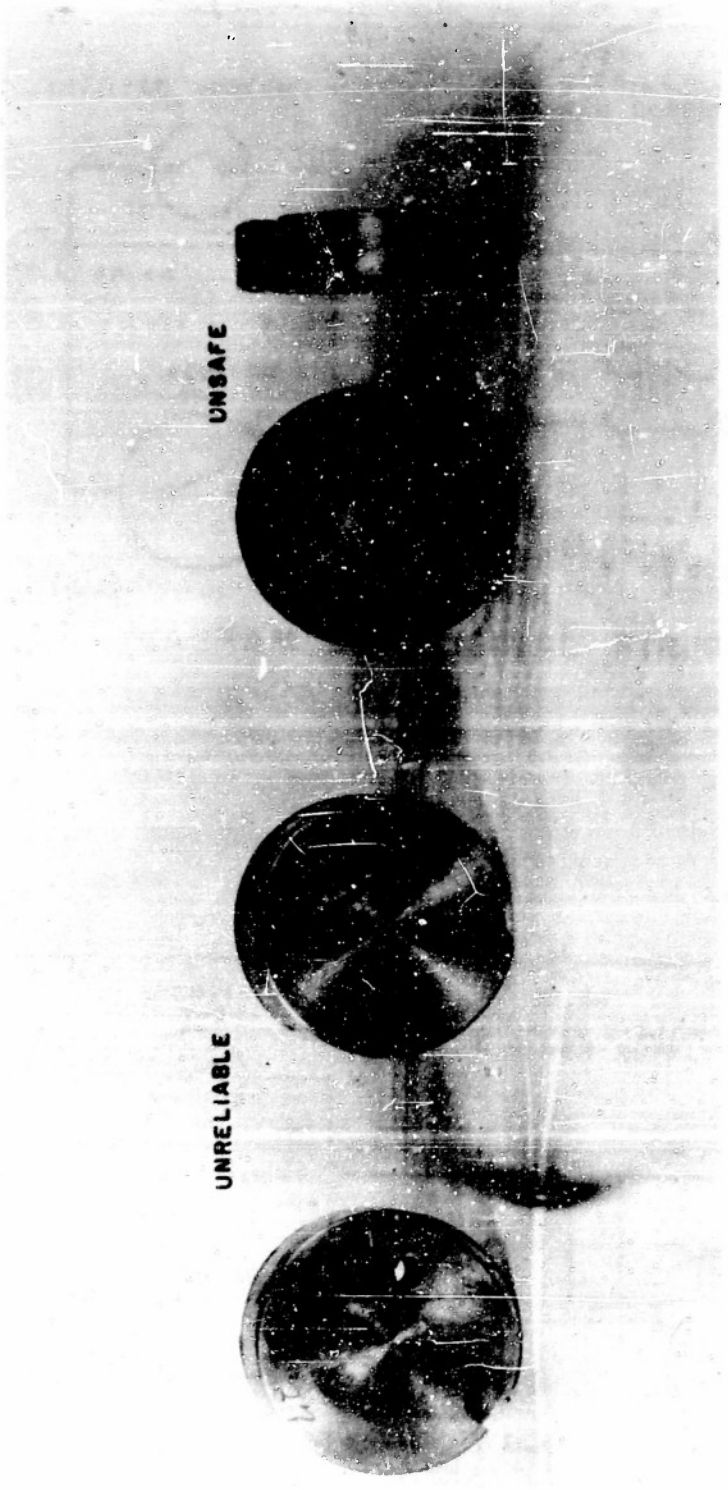


FIG. 7 LEAD DISCS FROM SAFETY AND RELIABILITY TESTS

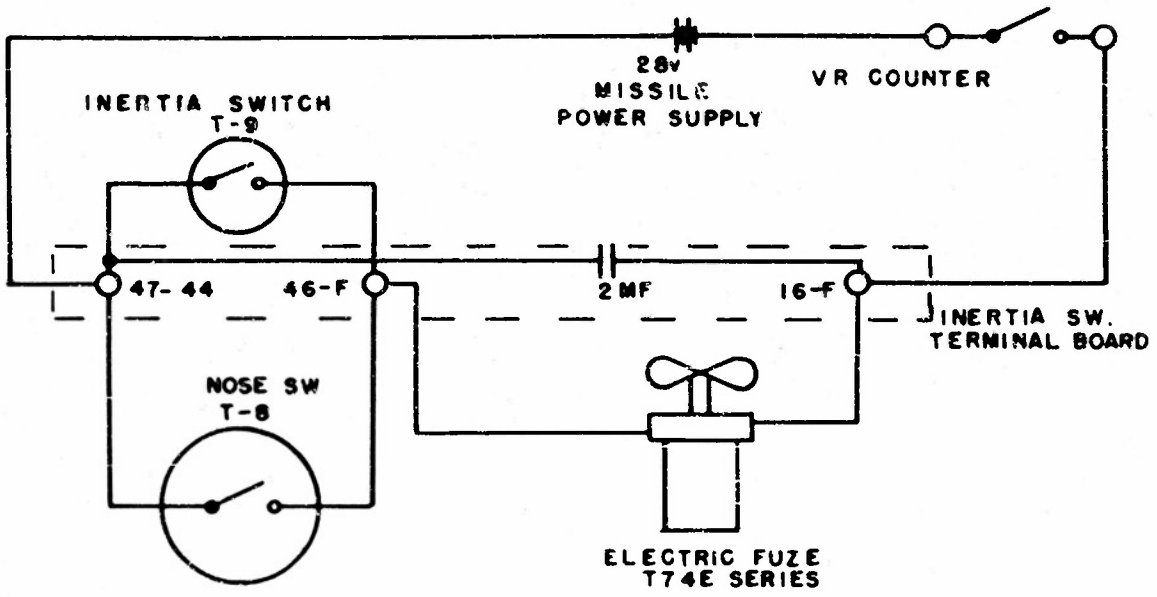


DIAGRAM OF ORIGINAL FIRING CIRCUIT

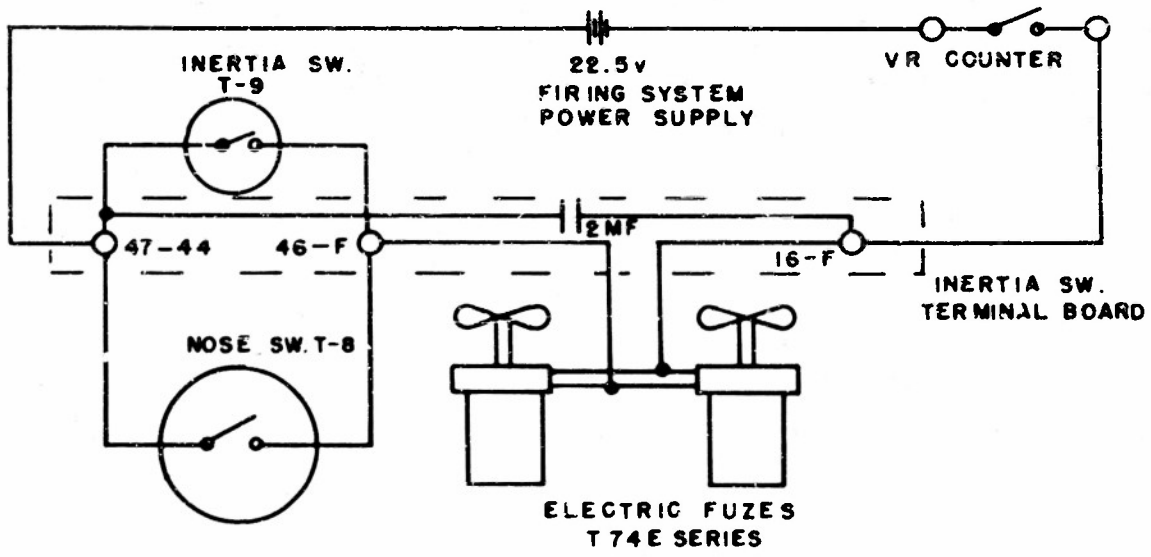
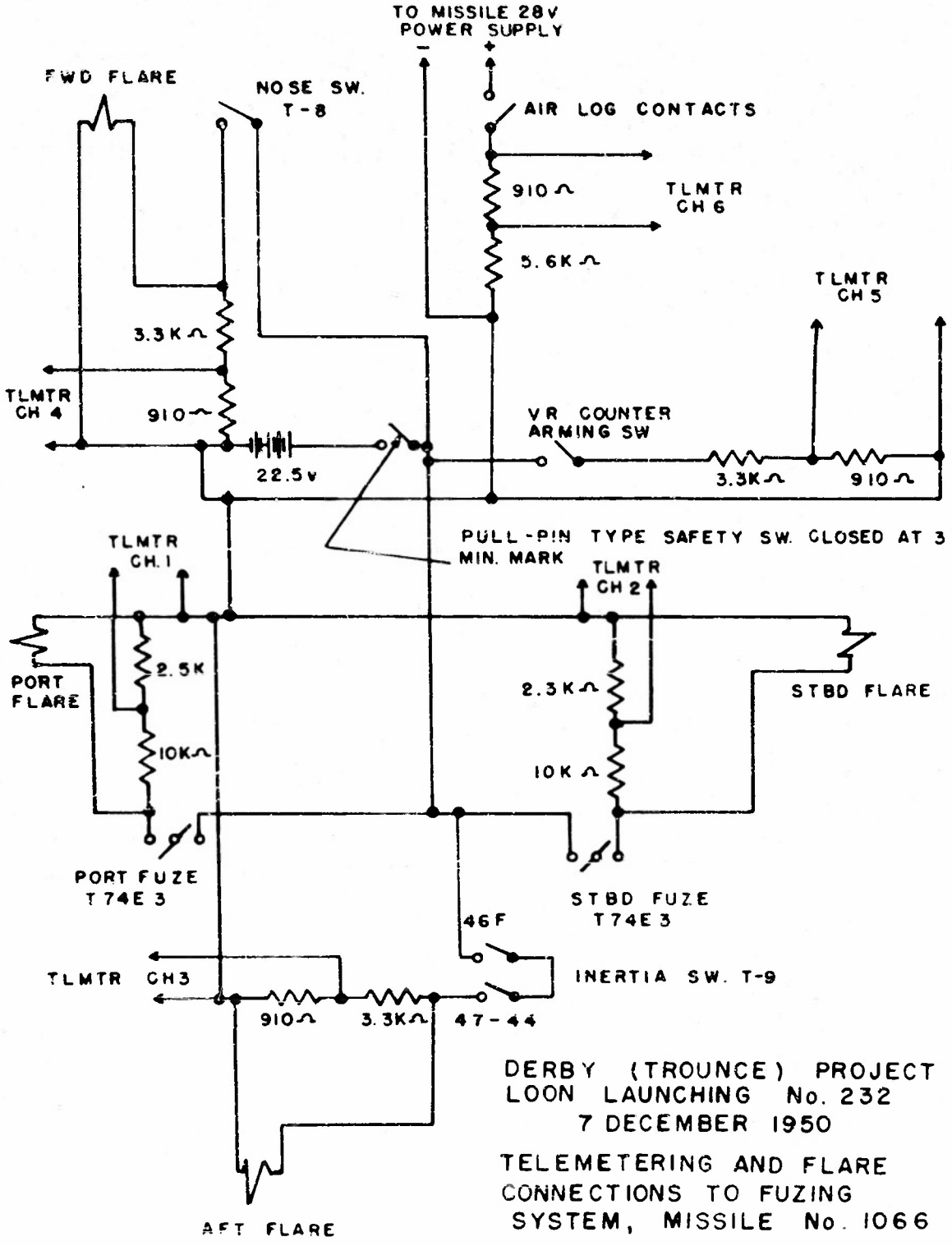


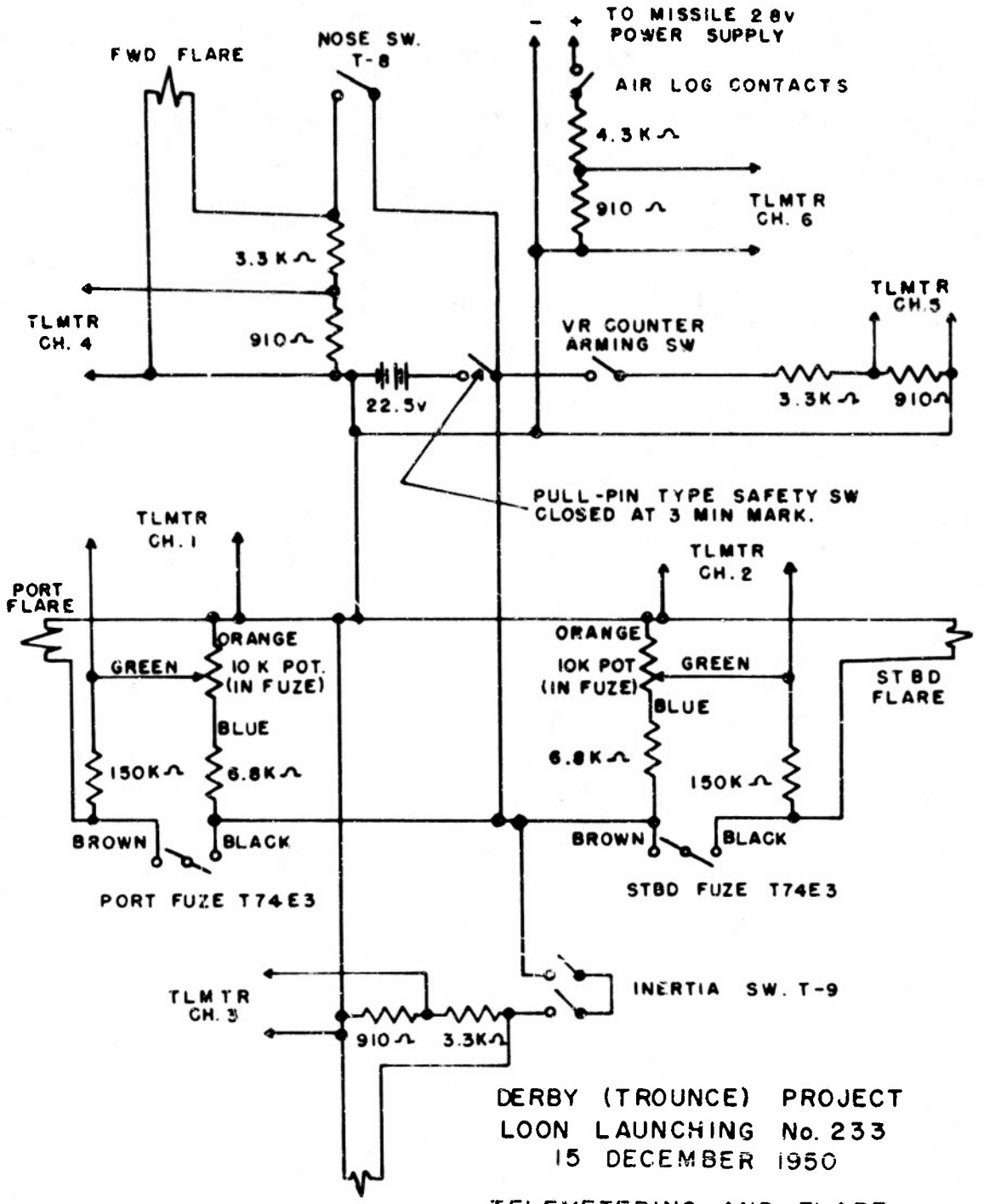
FIG. 8
DIAGRAM OF MODIFIED FIRING CIRCUIT



DERBY (TROUNCE) PROJECT
LOON LAUNCHING No. 232
7 DECEMBER 1950

TELEMETERING AND FLARE CONNECTIONS TO FUZING SYSTEM, MISSILE No. 1066

FIG. 9
TELEMETERING CONNECTION No. 1



DERBY (TROUNCE) PROJECT
LOON LAUNCHING No. 233
15 DECEMBER 1950

TELEMETERING AND FLARE CONNECTIONS TO FUZING SYSTEM, MISSILE No. 1028

FIG. 10
TELEMETERING CONNECTION No. 2

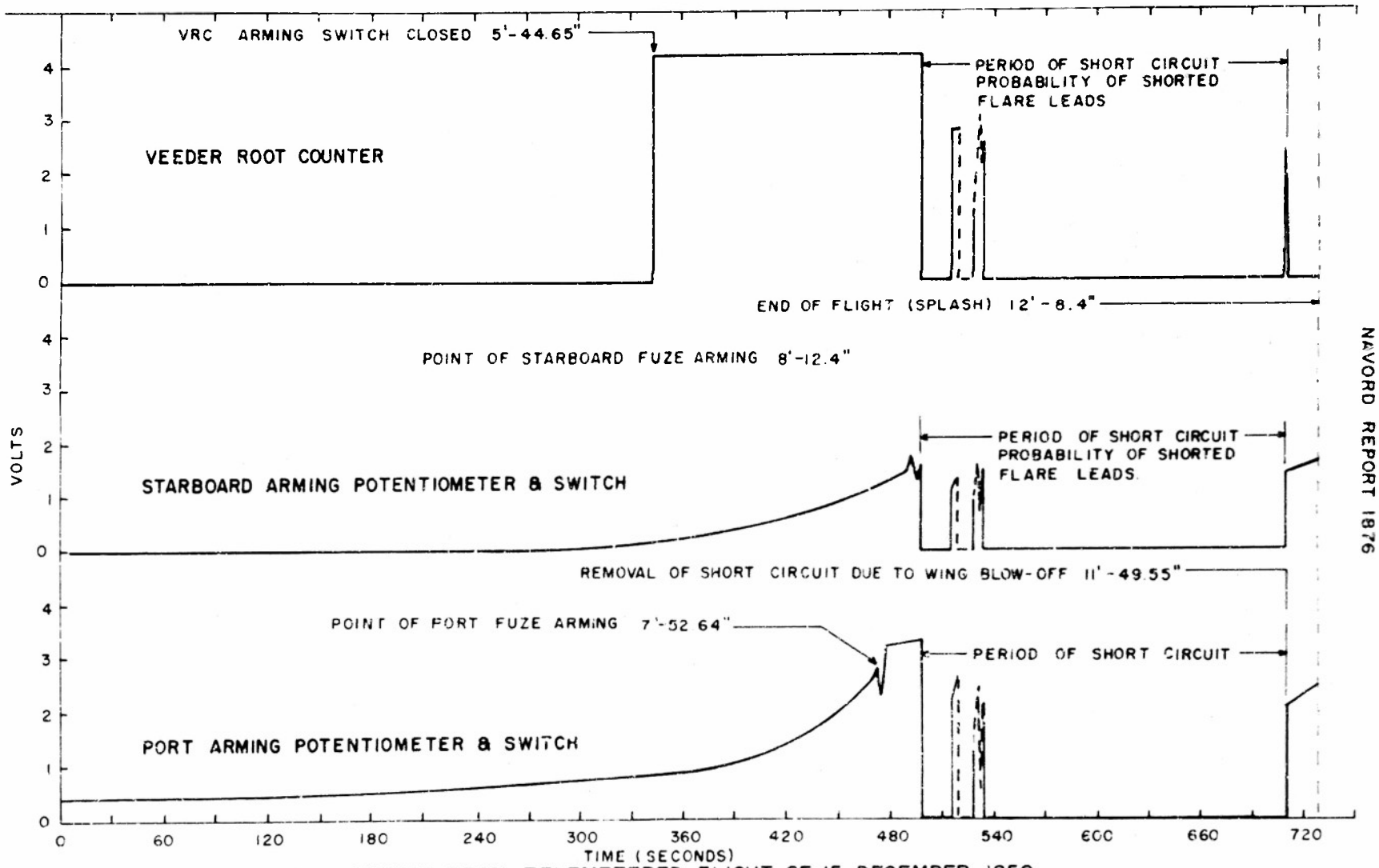


FIG. 11 CURVES FROM TELEMETERED FLIGHT OF 15 DECEMBER 1950

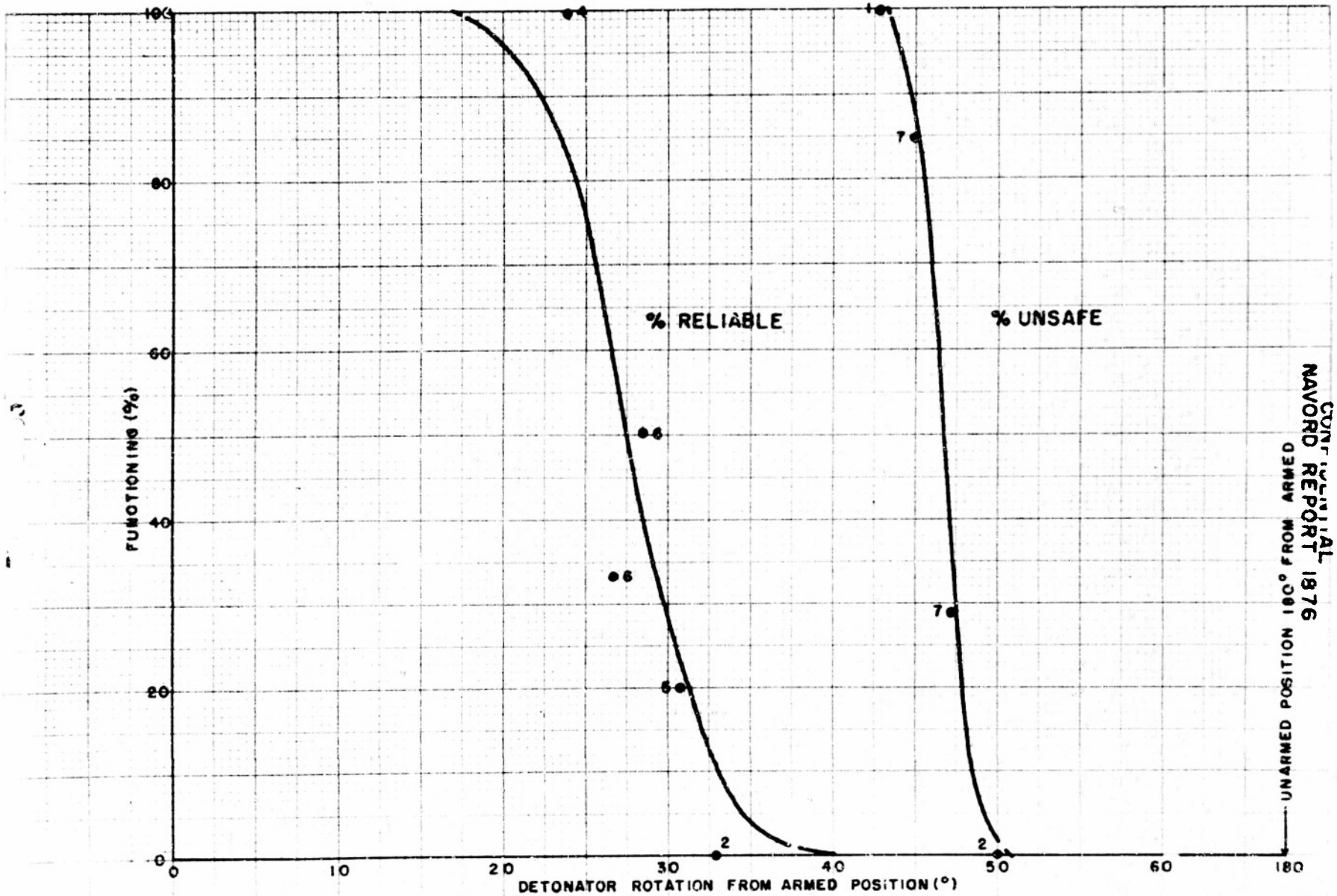


FIG.12 DETONATOR SAFETY AND RELIABILITY

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